Historical Development and Problems Within the Pennsylvanian Nomenclature of Ohio.[1]

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ABSTRACT. **An analysis of the historical development of the Pennsylvanian stratigraphic nomenclature, as used in Ohio, has helped define and clarify problems inherent in Ohio's stratigraphic nomenclature. Resolution of such problems facilitates further development of a useful stratigraphy and philosophy for mapping.**

Investigations of Pennsylvanian-age rocks in Ohio began as early as 1819. From 1858 to 1893, investigations by Newberry, I. C. White, and Orton established the stratigraphic framework upon which the present-day nomenclature is based. During the 1950s, the cyclothem concept was used to classify and correlate Pennsylvanian lithologic units. This classification led to a proliferation of stratigraphic terms, as almost every lithologic type was named and designated as a member of a cyclothem. By the early 1960s, cyclothems were considered invalid as a lithostratigraphic classification.

Currently, Pennsylvanian nomenclature of Ohio, as used by the Ohio Division of Geological Survey, consists of four groups containing 123 named beds, with no formal formations or members. In accordance with the 1983 North American Stratigraphic code, the Ohio Division of Geological Survey considers all nomenclature below group rank as informal.

OHIO J. SCI. 91 (1): 69–76, 1991

INTRODUCTION

Understanding the historical development of Pennsylvanian stratigraphy in Ohio is important to the Ohio Division of Geological Survey (OGS). Such an understanding of Pennsylvanian stratigraphy helps define stratigraphic nomenclatural problems in order to make clarifications. In 1985, as the Division was preparing geological maps for several counties in northeastern Ohio, the tracing of development of current Pennsylvanian nomenclature used by the Division was begun. This research was performed in order to understand past usage of the present nomenclature, anticipate any stratigraphic problems that may exist, and establish a suitable methodology before field mapping was initiated. Since then, field mapping and core drilling have revealed significant problems within the Pennsylvanian stratigraphic classification of the state. A thorough understanding of concepts and methods used by earlier geologists is required to resolve these stratigraphic problems and assure that the ensuing modifications are in accordance with sound stratigraphic principles.

This study traces and analyzes the historical evolution of Pennsylvanian stratigraphic nomenclature in Ohio. In addition, the current treatment of Pennsylvanian lithostratigraphy by the OGS is discussed. The accompanying correlation chart (Fig. 1) is intended to provide a general overview of the chronological development of the Pennsylvanian lithostratigraphy used by the OGS and to serve as a point of reference for the details given in the following discussion.

[1]Manuscript received 16 May 1990 and in revised form 2 February 1991 (#90-11).

DISCUSSION

The Early 1800s

The earliest known references to Pennsylvanian-age rocks in Ohio are found in Atwater's (1819) report on Belmont County, and an article by Granger (1821) on plant fossils collected near Zanesville, Muskingum County. Detailed stratigraphic work on the coal sequences of Ohio did not begin until the middle to late 1820s.

Hildreth (1826, 1827, 1828, 1833, 1836) established most of the stratigraphic framework that was adopted by the OGS during the period of its first organization from 1837 to 1838. Most noteworthy is Hildreth's 1836 geological report on the northern Appalachian coal region; this report contains a large number of detailed lithologic descriptions, regional correlations, discussion of paleontology, and analysis of the economic resources of the region, and Ohio in particular. The first detailed systematic classification applied to the Pennsylvanian rocks of Ohio is found in this report.

The classification scheme used by Hildreth and the first organization of the Ohio Geological Survey followed the late-1700s style of Abraham Gottlob Werner, the accepted stratigraphic standard prior to the early 1840s (Silliman 1832, Adams 1954, Newcomb 1989). In accordance with practices of the day, the rocks of the northern Appalachian region were nomenclaturally correlated with those of Great Britain (Hall 1843). Thus, the Pennsylvanian rocks in Ohio were subdivided, in ascending order and in the sense of Coneybeare and Phillips (1822), into The Conglomerate and the Coal Measures of Werner's Secondary Series. The Conglomerate was a term applied to Mississippian and Pennsylvanian conglomeratic quartzose sandstones occupying the stratigraphic position below the lowest known coal bed. The Conglomerate was believed to be the North American equivalent of the Millstone grit

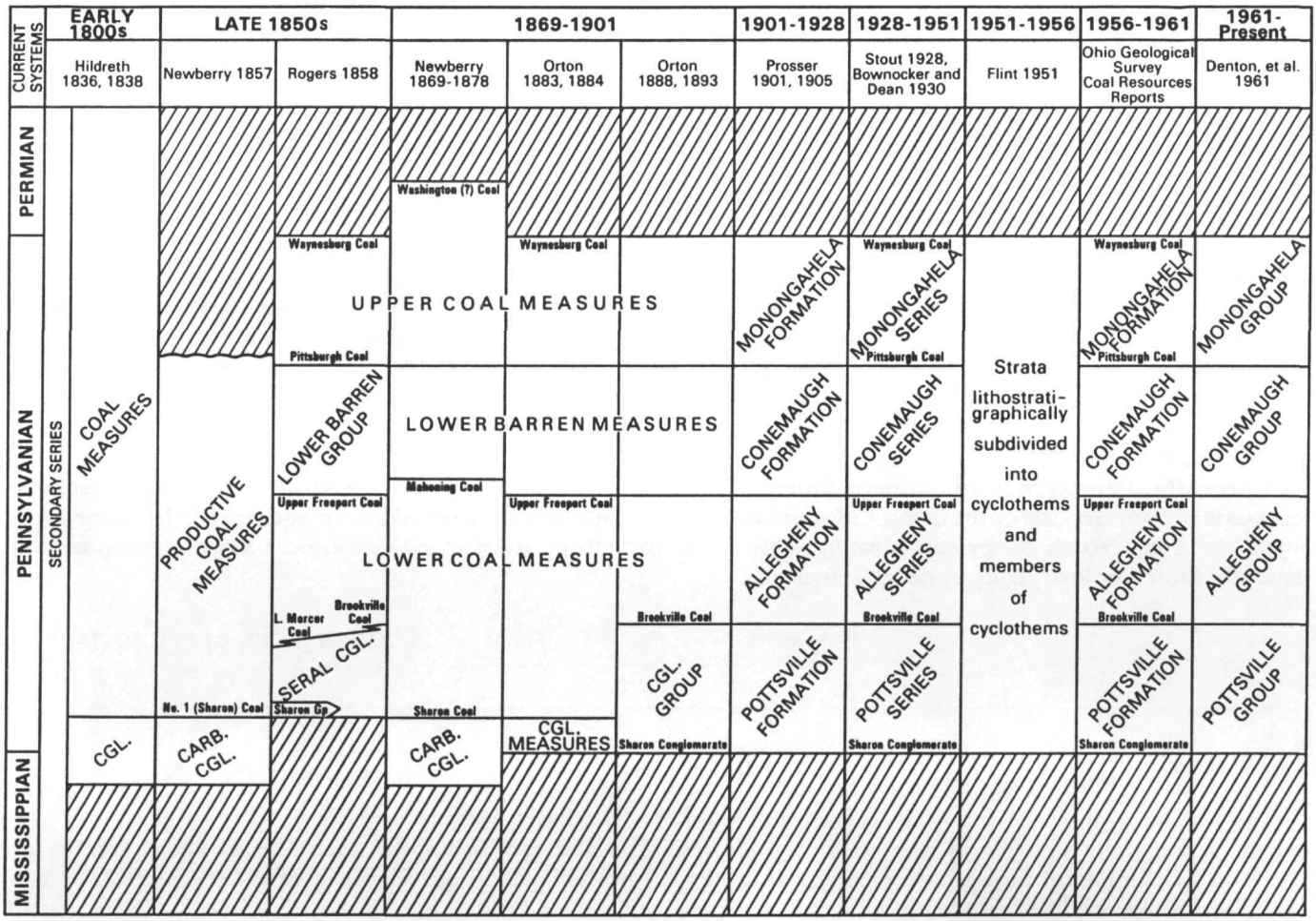

FIGURE 1. Correlation chart showing the historical development of the Pennsylvanian lithostratigraphic classification used by the Ohio Division of Geological Survey.

in Great Britain. The concept that these conglomerate sandstones were equivalent to the Millstone grit persisted throughout most of the 1800s and evolved to encompass the sequence of rocks that now comprise the Pottsville Group (Foster 1838, Dana 1871, Newberry 1874, Lesley 1876, Platt 1880).

The Coal Measures were defined as the sequence of rocks which included all the coal beds. Hildreth (1828, 1833, 1836, 1838) subdivided the Coal Measures in Ohio into an Upper and Lower Coal Series. He placed their contact at the base of a stratum of cherty limestone he termed the "Great Silicious Deposit" or the "Calcareo-Silicious Rock." Comparison of Hildreth's locality descriptions to more recent work (Norling 1958, Sturgeon et al. 1958, DeLong 1972) suggests Hildreth incorrectly correlated the cherty limestone facies that occur within the stratigraphically separate Vanport, Brush Creek, and Ames marine zones (Fig. 2) as a single laterally-continuous stratum.

The Late 1850s

In 1838, the first Geological Survey of Ohio was dissolved by the state legislature (Hansen and Collins 1979). The period from 1838 to the organization of the second Geological Survey of Ohio in 1869 was a time of rapid advances in the science of geology in North America. Unfortunately, geological work in Ohio, as a whole, was minimal. In spite of this, the late 1850s were a very important period in establishing the current Pennsylvanian lithostratigraphic classification currently used in Ohio.

The classification and nomenclature used now by the OGS are based on studies by Newberry (1857) in northeastern Ohio, and by Rogers (1858) of the first Pennsylvanian Geological Survey in western Pennsylvania. Newberry introduced a numbering system to identify economic coal beds of the region. Though modified, this numbering system is still used today. Rogers (1858) established the fundamental criteria upon which our current classification is based. Rogers subdivided the coal-bearing rocks into five main subdivisions which were, in ascending stratigraphic order, the Seral Conglomerate, Lower Coal Measures, Lower Barren Group, Upper Coal Measures, and Upper Barren Group. The Upper Barren Group included strata that were later assigned to the Permian System by Fontaine and White (1880).

The subdivisions used by Rogers have received some criticism for being defined on the basis of coal economics and not on lithologic differences (Moore and Thompson 1949, Lamborn 1951, Collins 1979). However, Rogers' original definitions and usages of the terms were based on lithostratigraphic criteria. The argument for an economic basis stems from the fact that the boundaries between the rather broad lithostratigraphic subdivisions were somewhat arbitrarily placed relative to coal beds as a matter of convenience (Rogers 1858), and the names chosen re-

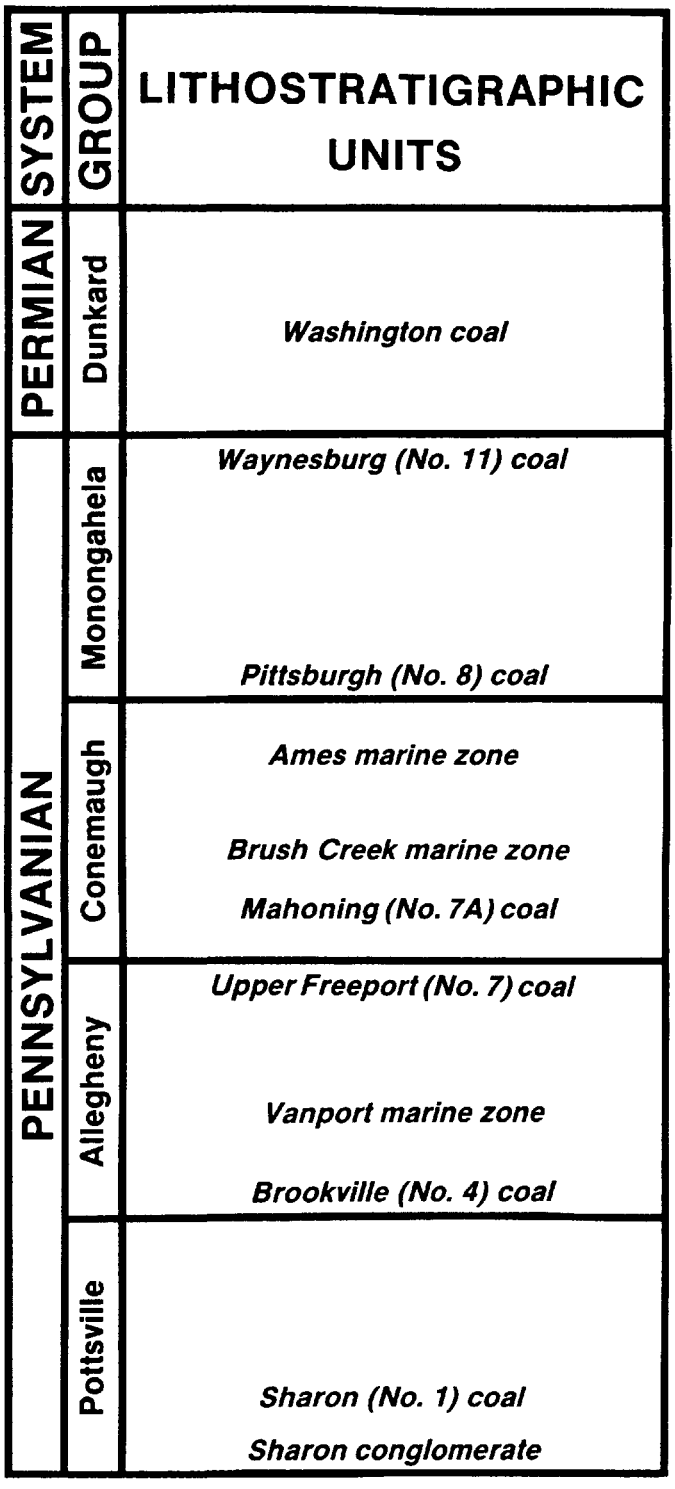

FIGURE 2. Stratigraphic column showing approximate positions of several key beds in Ohio.

flected the relative abundance of coal.

The nomenclature used by Rogers and Newberry incorporated some of the terms and concepts utilized in Great Britain during the early 1800s. Both classifications retained the concept of the Coal Measures underlain by a thick basal conglomerate (termed the Conglomerate, Carboniferous Conglomerate, or Seral Conglomerate) (Fig. 1). However, stratigraphic placement of the Conglomerate by Newberry was different from that of Rogers. Newberry (1857) placed the Conglomerate below the Sharon coal, encompassing the basal Pennsylvanian Sharon conglomerate (of modern usage) and the uppermost conglomerates of the Mississippian Cuyahoga Formation. Rogers (1858) placed the Conglomerate (or Seral Conglomerate) above the Sharon coal and included the Sharon coal as the basal member of the Seral Conglomerate.

This disparity concerning the stratigraphic position of the Conglomerate prompted a long debate among geologists from Ohio and Pennsylvania. Pennsylvania geologists contended that Ohio geologists had misidentified the Mississippian Berea Sandstone as the Conglomerate. Ohio geologists thought the interval containing the conglomeratic sandstone below the Sharon coal was the true representative of the Conglomerate (Newberry 1874; Lesley 1875, 1879; Chance 1879; Orton 1884a). By the late 1880s, however, geologists from both Ohio and Pennsylvania were classifying the interval from the base of the Sharon conglomerate to the base of the Brookville coal (or top of the underlying Homewood sandstone) as the Conglomerate Group (I.C. White 1880, 1891; Orton 1888; Ashley 1945).

1869 to 1901

The Geological Survey of Ohio was reorganized in 1869 with Newberry as Chief Geologist (Hansen and Collins 1979). As a result, the Pennsylvanian nomenclature and stratigraphic framework of Ohio underwent a renaissance from 1869-1901. Geologic mapping from 1869 to 1882 by Newberry, Andrews, Stevenson, Read, Hodge, and Orton, established a stratigraphic classification from which the current Pennsylvanian classification in Ohio developed.

The classification used by the OGS from 1869 to 1882 was a combined adaptation of Newberry's (1857) coal-bed-numbering system and Rogers' (1858) Coal Measures subdivisions (Newberry 1870, 1871, 1874). Rogers' subdivisions were redefined, with a greater emphasis placed on the relative abundance of commercially mineable coal. Thus, the top of the Upper Coal Measures was changed from the top of the Waynesburg coal to the top of the stratigraphically higher Washington(?) coal (Newberry 1878a), so that all the known mineable coals above and including the Pittsburgh coal bed, were grouped into the Upper Coal Measures. Similarly, the upper and lower boundaries of the Lower Coal Measures were changed. This change resulted in all economically important coal beds occurring in the interval between and including the Sharon and Mahoning coals being placed in the Lower Coal Measures (Newberry 1871). Also, this new classification placed the Conglomerate (Carboniferous Conglomerate) (Fig. 1) below the Sharon coal, a view which reflected Newberry's (1857, 1878b) idea that the true representatives of Rogers' Seral Conglomerate in Ohio were the conglomeratic sandstones underlying the Sharon coal bed.

In 1882, Edward Orton succeeded Newberry as the State Geologist of Ohio. Orton (1883, 1884a) restudied, renamed, and reorganized the stratigraphy of the Coal Measures given by the Newberry survey. Orton (1883) opposed the use of Newberry's numbering system because he felt it was misleading, created confusion in identifying coals, and did not provide a satisfactory framework for mapping. Thus, Orton (1883, 1884a) proposed that Ohio abandon the numeric nomenclature and adopt the nomenclature used by

the Pennsylvania Geological Survey. Several reasons for Orton's proposed changes were: 1) the "laws" of stratigraphic nomenclature required stratigraphic units be known by the names where they were first described; 2) the principal units known from Pennsylvania's coal fields were first named and classified by the Pennsylvania Geological Survey between 1836 and 1858, long before the Newberry survey developed a suitable stratigraphic framework for Ohio; and, 3) I. C. White (1879) of the Pennsylvania Survey provided detailed stratigraphic correlations between the coal fields of northeastern Ohio and those of western Pennsylvania (Orton 1883, 1893).

In adopting Pennsylvania's classification and nomenclature, Orton readjusted the boundaries of the Lower Coal Measures, Lower Barren Measures, and Upper Coal Measures in order to agree with the original positions as proposed by Rogers (1858). The only exception was the retention of Newberry's placement of the Conglomerate-Lower Coal Measures boundary at the base of the Sharon coal (Orton 1884a). Orton (1888) later reconsidered the position of this boundary and adopted Pennsylvania's boundary placement at the base of the Brookville coal (Fig. 1). Orton (1883, 1884b) also revised Newberry's coal-bed numbers into the current form. This is interesting because Orton had suggested (1883) that the numerical classification should be abandoned. Apparently Orton had anticipated a negative reaction by Ohio's coal industry, who preferred to keep the number system of Newberry and opposed any adoption of another classification (Orton 1883, Roy 1884).

1901 to 1928

Orton's revised Coal Measures classification was the standard used by the OGS until Prosser revised the stratigraphic framework for Ohio in 1905. Revisions by Prosser included changing names used for the four main subdivisions of the Pennsylvanian System (Fig. 1). Earlier, Prosser (1901) had proposed that the formational names applied to Rogers' subdivisions by the Maryland Geological Survey (O'Hara 1900) be adopted in Ohio. Prosser was concerned that the terms Lower Coal Measures, Lower Barren Measures, and so forth, related to the economic value of the subdivisions and did not conform to the accepted stratigraphic principle that stratigraphic units should be named after the geographical areas where they were first described. Therefore, in accordance with the stratigraphic principles of the day, the following name changes were adopted by the OGS in 1905:

OLD NAMES (FROM ORTON 1888)	NEW NAMES (FROM O'HARA 1900)
Upper Coal Measures	Monongahela Formation
Lower Barren Measures	Conemaugh Formation
Lower Coal Measures	Allegheny Formation
Conglomerate Group	Pottsville Formation

By adopting these terms, the OGS had essentially established the current classification used for Pennsylvanian strata in the state.

1928 to 1951

Prior to 1951, the OGS used a dual system of stratigraphic nomenclature for sedimentary rocks. This dual system was similar to that adopted by the U.S. Geological Survey (Walcott 1903, Wilmarth 1925), and later by Ashley et al. (1933), which separated rock units from time units. The units constituting the dual classification system were:

ROCK UNITS	TIME UNITS
	Era
System	Period
Series Group Formation Member	Epoch

From 1928 to about 1947, the stratigraphic terms Pottsville, Allegheny, Conemaugh, and Monongahela were ranked by the OGS as series instead of formations. The reason behind this hierarchical change is not known. Monongahela first appeared as a series term in a published abstract by Stout in 1928. Pottsville, Allegheny, and Conemaugh appeared as series, along with Monongahela, the following year in the "Generalized section of the Pennsylvanian System" in Bownocker and Dean (1929).

The series were subdivided into members. No subdivisions other than members were made. Subdivision of series into members without formations was inconsistent with accepted stratigraphic practices of the day. No reason was ever given for this omission in the stratigraphic hierarchy. It is possible (though strictly conjecture) that some sort of formational subdivision based on the concept of cyclical deposition may have been considered.

The concept of classifying Pennsylvanian rocks on the basis of cyclical deposition had been implemented many years prior to the stratigraphic changes made by the OGS in 1928 and 1929. Udden (1912) noticed a cyclic or repetitive nature within the Pennsylvanian rocks of central Illinois and was the first to subdivide the strata using these cyclic sequences. In this report, Udden defined the succession of strata from the base of one coal bed to the next adjacent one as a cycle of deposition (or a single cyclic sequence). Stout et al. (1923) also noticed the repetitive nature of the Pennsylvanian rocks in Ohio, and devised a model of cyclical deposition to explain how Pennsylvanian rocks were deposited.

Weller (1930,1931) advanced the concepts of Udden (1912) and Stout et al. (1923) by establishing a rock classification which subdivided the Pennsylvanian strata of Illinois into formations based on cycles of sedimentation. Each cyclical formation (termed cyclothem by Wanless and Weller in 1932) as defined by Weller (1931) had the following succession of strata:

9. Shale, ferriferous.
8. Limestone, marine.
7. Shale, calcareous.
6. Shale, carbonaceous.
5. Coal.
4. Underclay.
3. Limestone, "fresh-water."
2. Shale, sandy and micaceous.
1. Sandstone.

Unconformity.

Stout (1931) discussed in detail the cyclical nature of the Pennsylvanian strata in Ohio. He subdivided the Pennsylvanian stratigraphic section into cyclical sequences. Each cycle was defined as the interval of strata occurring between adjacent coal beds. The boundary between cycles was placed at the base of the coal beds. This was essentially the same as Udden's (1912) original proposal. However, the OGS did not adopt a classification based on cyclical sequences (or cyclothems) until 1951.

In 1947, the American Commission on Stratigraphic Nomenclature revised the dual system of classification into three categories by adopting time-rock or chronostratigraphic units. System and series were redefined as chronostratigraphic units. These classification changes may have created some confusion at the OGS as to the correct usage of the terms Pottsville, Allegheny, Conemaugh, and Monongahela. In 1949, G. W. White defined these terms as formations. Sturgeon and Merrill (1949) referred to the four subdivisions as formations or series. By 1951, however, the OGS adopted Pottsville, Allegheny, Conemaugh, and Monongahela as chronostratigraphic series terms.

The 1950s and Cyclothems

From 1951 to 1958, the OGS was actively involved in mapping Pennsylvanian rocks and calculating the coal resources of Ohio (Smith 1952, Denton 1959). Accurate coal-bed correlations were a primary concern and increased the need for detailed stratigraphic work. The Perry County bulletin (Flint 1951) was the first report published through this program (Smith 1952, Norling 1958). This report marked the first formal use by the OGS of Pottsville, Allegheny, Conemaugh, and Monongahela as chronostratigraphic series. These terms were defined as series in accordance with the Pennsylvanian Subcommittee of the National Research Council Committee on Stratigraphy (1944) definition, which based the terms on fossil floral zones.

Flint (1951) also adopted the cyclothemic classification for Pennsylvanian lithostratigraphic units, as proposed by Weller (1930, 1931) and Wanless and Weller (1932). In practice, the cyclothem was treated as a mappable lithostratigraphic unit equivalent to a formation. Individual cyclothems were formally named, generally after the primary key bed contained within each cycle (Fig. 3). Also, there was a tendency to apply the name of the cyclothem to unnamed strata within each cycle. This nomenclatural practice led to the proliferation and duplication of stratigraphic terms, so that nearly every bed of shale, sandstone, clay, and so forth, was named and formally ranked as a member (Fig. 3).

The arrangement of cyclothems in regard to the placement of boundaries between cycles was arbitrary (Stout 1954, Norling 1958, Ferm 1975). The question concerning the stratigraphic position of the boundary between cyclothems became a major issue for the OGS. Opinions on the boundaries differed among Survey stratigraphers. Boundaries between cyclothems were placed at the base of sandstones, the base of coal beds, the top of coal beds, and at the base of underclays, without any general agreement (written communications of: J. Hall to R. J. Bernhagen 1 March 1955; W. M. Merrill to Bernhagen 13 August 1956). Therefore, in 1956, the policy regarding the use of the cyclothemic classification by the OGS was revised. In a letter written by then Assistant Chief, R. J. Bernhagen (30 August 1956), to W. M. Merrill, Bernhagen wrote:

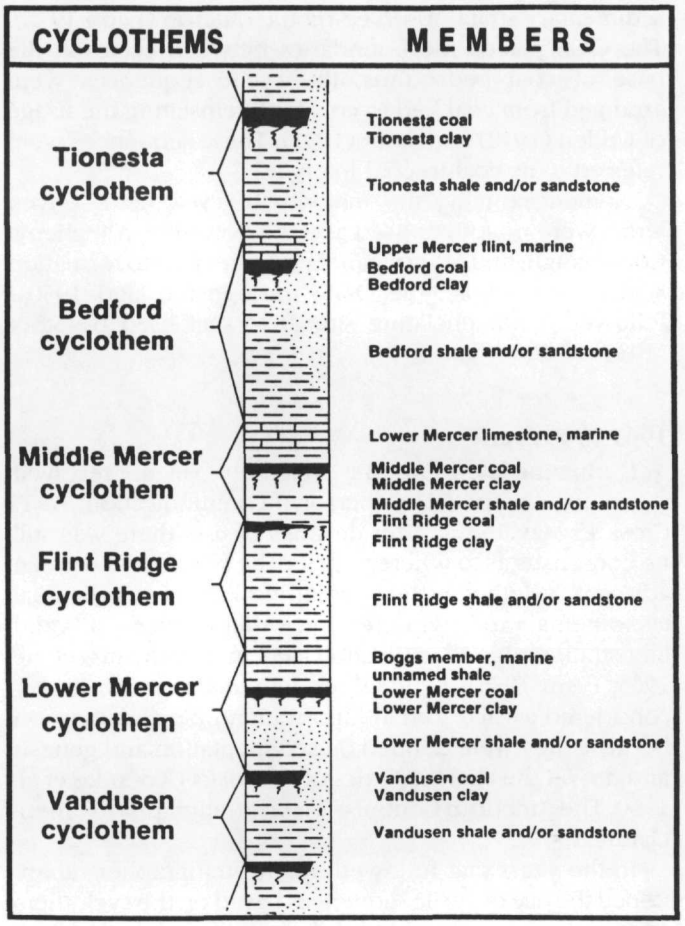

FIGURE 3. Diagram showing cyclothemic nomenclature used for Pottsville strata in Ohio (adapted from Flint 1951).

> ". . . The principal reason for this letter is to state definitely a policy regarding the use of cyclothems in Ohio Geological Survey Reports....In view of the fact that there is no agreement among Pennsylvanian stratigraphers in establishing cyclothemic boundaries and in view of the fact that this indecision is and has been leading to confusion the Ohio Geological Survey will in future publications abandon the use of cyclothems in the stratigraphic descriptions as used in the Perry County Bulletin...."

The Athens County bulletin (Sturgeon et al. 1958) was an exception to this policy. The work had been in progress since the late 1940s (Melvin 1951) and the manuscript was nearly complete in 1956. Thus, the OGS had no desire to make major changes in the manuscript at such a late stage.

As of 1956, the OGS abandoned the cyclothem as a lithostratigraphic classification, but the concept of cyclical sedimentation was employed extensively for correlating and compiling lithostratigraphic data. The concept represented the best model available to Pennsylvanian stratigraphers to explain the complex variations of the

sedimentary strata observed on the outcrop (Ferm 1975). The OGS placed the boundaries between cycles at the base of coal beds; thus, the cyclic sequences were arranged from coal bed to coal bed, reinstating the usage of Udden (1912) and Stout (1931). These sequences were referred to as coal-to-coal intervals.

Nomenclaturally, the majority of cyclothem-derived terms were no longer used and the Pottsville, Allegheny, Conemaugh, and Monongahela were revised to formation status. As a whole, the OGS (through the later 1950s) followed a nomenclature similar to that used by Stout (1939, 1947).

1961 to Present

During the late 1950s, the cyclothem concept received much negative criticism (personal communication, A. T. Cross 15 May 1989). After decades of use, there was still no consensus as to where to place the boundary between adjacent cyclothems, the geographical limits of individual cyclothems, and whether cyclothems were a valid lithostratigraphic classification scheme (Williams et al. 1964, Ferm 1975). By 1960, cyclothems were no longer considered a valid formal lithostratigraphic classification because they were defined on sedimentation and genesis and not on the characteristics of the rocks (Kosanke et al. 1960, The American Commission on Stratigraphic Nomenclature 1961).

In the years that followed, many stratigraphers abandoned the use of cyclic sequences based on the cyclothem concept because it could not adequately explain the rapid facies changes and complex lateral variations commonly associated with Pennsylvanian-age sediments (Ferm 1975). The cyclothem model has since been replaced by deltaic depositional models to explain the rocks of the Appalachian coal region (e.g., Williams and Ferm 1964; Ferm and Cavaroc 1969; Ferm 1970, 1974; Donaldson 1974).

As the cyclothem theory became outdated, the Pennsylvanian stratigraphic nomenclature in Ohio was once again revised. Sometime around 1961, the OGS raised the stratigraphic rank of the Pottsville, Allegheny, Conemaugh, and Monongahela from formation to group. This revision appears to have been influenced by work conducted by the Pennsylvania Geological Survey on the 1960 Geologic Map of Pennsylvania (Gray et al. 1960). This map referred to the Pottsville and Allegheny as groups, and Conemaugh and Monongahela as formations. According to E. F. Koppe (written communication, 24 May 1989), prior to 1960, the Pennsylvania Geological Survey subdivided the Pottsville and Allegheny strata into mappable units deserving formation status. However, group rank was not given to the Monongahela and Conemaugh until the two units were redefined by Berryhill and Swanson (1962) and Flint (1965), respectively.

While the Pennsylvania geologic map was being completed, many people were asked to review the manuscript (written communication, E. F. Koppe 24 May 1989); one of the reviewers was then OGS Chief, R. J. Bernhagen. Apparently, Bernhagen did not care for Pennsylvania's "mixed" usage of formation and group terms as applied to the Pottsville, Allegheny, Conemaugh, and Monongahela. In a letter to J. E. Johnston of the U.S. Geological Survey (29 February 1960) Bernhagen wrote:

> "We are in the process of preparing several reports in which Pennsylvanian stratigraphy is involved. After having reviewed the preliminary sheet of the new Geologic Map of Pennsylvania I am more confused than ever. Just what is to be accepted as standard usage for the divisions of the Pennsylvanian- series, formation, group?
>
> Where possible we want to conform so will you kindly give me the current usage of the U.S.G.S."

The specifics of the response from the U.S. Geological Survey to Bernhagen's question is not known. However, the following year the OGS began to formally classify Pottsville, Allegheny, Conemaugh, and Monongahela as groups (e.g. Denton et al. 1961, DeLong and White 1963). Since 1961, the Pennsylvanian lithostratigraphic classification adopted by the Ohio Division of Geological Survey consists of four groups subdivided into informal members or beds. With the possible exception of the Conemaugh Group, formational subdivisions have not been made.

The Glenshaw and Casselman Formations (Flint 1965), used in Pennsylvania and West Virginia to divide the Conemaugh Group, have been applied to the Ohio Conemaugh Group (Donahue and Rollins 1974, Busch and Rollins 1984) in an attempt to correlate Conemaugh marine events and episodic sequences over the northern Appalachian Basin. However, the OGS has not adopted or recognized the Glenshaw and Casselman as formal formational divisions of the Conemaugh Group in Ohio. Hull (1990) lists the Glenshaw and Casselman as formations of the Conemaugh Group on the "Generalized Column of Bedrock Units in Ohio," but these terms are regarded as informal, pending formal definition and adoption.

CONCLUSION

Stratigraphic work on the Pennsylvanian rocks of Ohio has spanned more than 171 years. Traditionally, the rocks have been treated as laterally persistent units. Consequently, much of the nomenclature applied to the strata evolved from this concept. However, these stratigraphic units generally lack lateral continuity, and facies changes over short distances are common. Only a few lithologic units have shown some lateral persistence so as to be useful for widespread correlations and have been referred to as "key beds" by earlier workers. These persistent units generally are marine limestones and shales, but include a select number of coal beds.

Through a history of 171+ years of stratigraphic work on the Pennsylvanian rocks of Ohio, the OGS has inherited a lithostratigraphic classification consisting of four groups containing 123 named beds, with no formal formational subdivisions. Because the Pennsylvanian stratigraphic nomenclature of Ohio is not subdivided into formations—the basic unit of classification and nomenclature—the OGS, in accordance with the American Commission on Stratigraphic Nomenclature (1983), considers all

nomenclature below the rank of group as informal. Many of the named strata in the groups are not mappable and lack distinctive lithologies necessary to be useful in determining local or regional correlations, structure, or economic resources. Therefore, only the beds that are valuable as "key beds" for determining stratigraphic sequences and correlations are nomenclaturally recognized.

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